

## CNS Emergencies: Trauma

James G. Smirniotopoulos, M.D.  
Professor of Radiology, Neurology,  
and Biomedical Informatics  
Chair, Department of Radiology



Uniformed Services University  
Bethesda, MD  
<http://rad.usuhs.mil>

USUHS - Smirniotopoulos

## Trauma Pathophysiology Matrix

	Non-Contact	Impact
Primary Injury	DWI/DWI	Contusion: -Coup -Contre-Coup
Secondary Injury	Subdural Hematoma	Epidural Hematoma

## CNS TRAUMA

- IMPACT
  - CONTACT INJURY
  - scalp/skull Abnormal
- INERTIAL
  - NON-CONTACT INJURY
  - acceleration/deceleration
  - scalp/skull Normal

<http://rad.usuhs.mil>

## Roller Coaster Headache

- Roller Coasters can create 2.5 – 3 G's
- Grandpa rides with Granddaughter
  - She's screaming with excitement
  - He's subdued by Subdural
- Reference:  
Fukutake T, Mine S, Yamakami I, Yamaura A, Hattori T. Roller coaster headache and subdural hematoma. Neurology. 2000 Jan 11;54(1):264. PMID: 10636168; UI: 20100123

<http://rad.usuhs.mil>

## Types of Injury

- Primary Lesions
  - Contusions
  - Shearing Injury
- Secondary Lesions
  - Mass Effect
  - Increased ICP
  - Herniation
  - Infarction

<http://rad.usuhs.mil>

## Workplace Injury



Radiology Attending

## Relative Sensitivity

- MR Spectroscopy (decreased NAA)
- Magnetization Transfer Ratio
- Apparent Diffusion Coefficient
- Diffusion Weighted Imaging
- FLAIR
- Convention SE MR (T2W > T1W)
- CT (ECT > NCT)
- Skull Radiogram

## Subgaleal Hematoma



## CENTRIPETAL APPROACH

- SCALP
- CALVARIUM
- EPIDURAL
- SUBDURAL
- SUBARACHNOID
- INTRA-PARENCHYMAL
- INTRA-VENTRICULAR

## Linear Skull Frx



## CNS TRAUMA -- SUBGALEAL

- Between periosteum of OUTER table and the GALEA (under scalp fat)
- In CHILD, significant blood loss
- Spontaneous decompression of intracranial (Epidural) hematoma

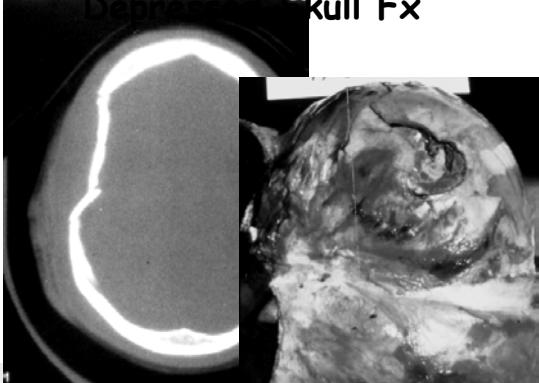
### Depressed Skull Frx



### MEMBRANE HEMATOMAS:

- SUBGALEAL
- SUBPERIOSTEAL OUTER TABLE
  - (CEPHALOHEMATOMA)
- SUBPERIOSTEAL INNER TABLE
  - EPI (EXTRA) DURAL
- Subdural ('epi-arachnoid')
- SUBARACHNOID
- PARENCHYMAL HEMATOMA
- INTRA-VENTRICULAR

### Skull Frx



### CNS TRAUMA EPIDURAL HEMATOMA

- Young men (20-40's)
- Acute presentation
- Skull fracture (90%)
- Bi-convex, hyperdense- limited by sutures

### Ballpeen Hammer



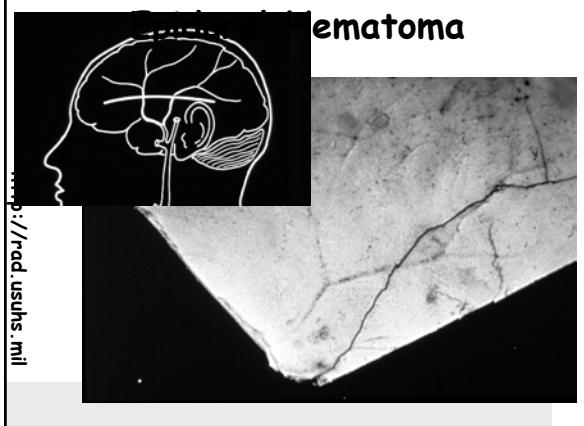
### EPIDURAL HEMATOMA - Source of Bleeding

- MENINGEAL VESSELS
  - Arterial (high pressure)
  - Venous (low pressure)
- DURAL SINUS
  - High flow, low pressure
- OTHER
  - Diploic veins (Fx)
  - Marrow sinusoids

## EPIDURAL HEMATOMA

- Significant trauma
- Fracture & concussion (l.o.c.)
- Wakes up (lucid interval - 40% pts.)
- Delayed neurologic Sx (hrs. Later)
- Herniation, coma and death

<http://rad.usmhs.edu>



## EPIDURAL HEMATOMA

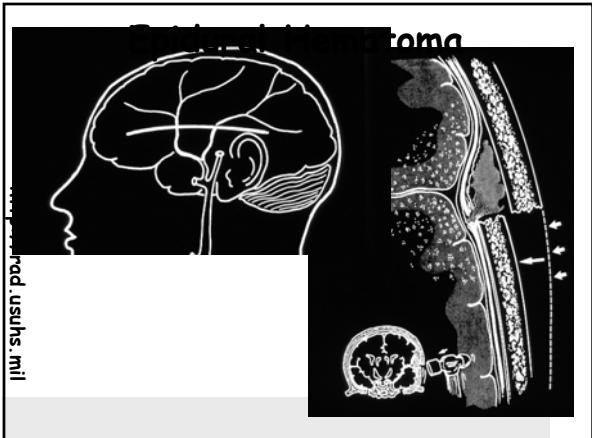
- Trauma -> fracture & concussion
- Tearing/stripping of both layers from inner table
- Laceration of outer periosteal layer
- Laceration of meningeal vessels
- Inner (meningeal dura) intact
- Blood between naked bone and dura



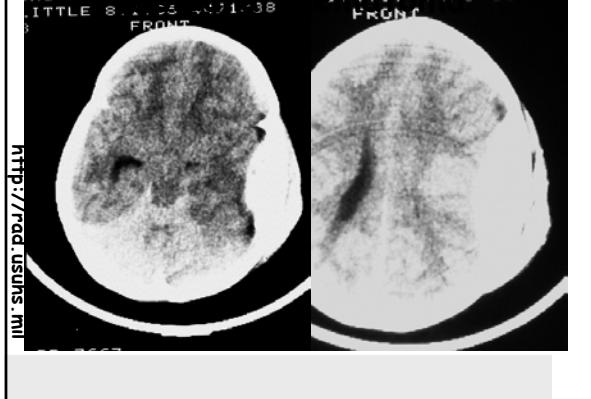
## Epidural Hematoma



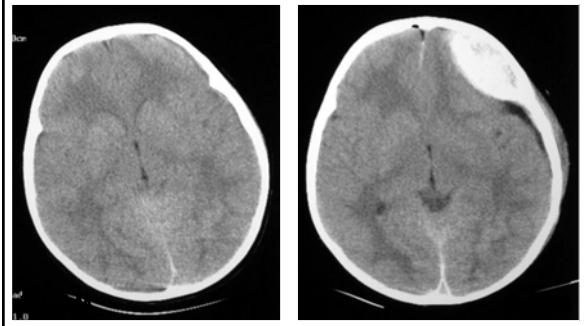
<http://rad.usmhs.edu>



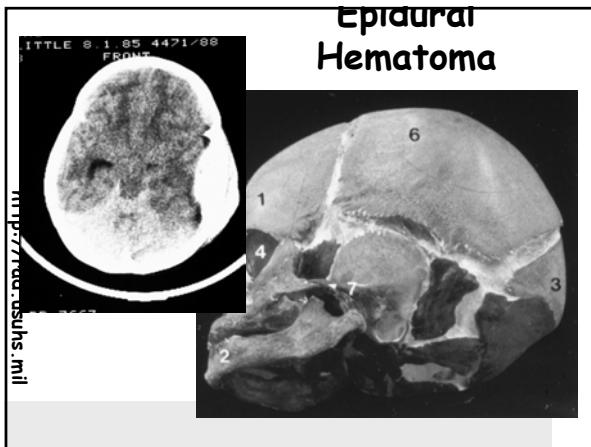
### Epidural Hematoma



### Progressive EDH



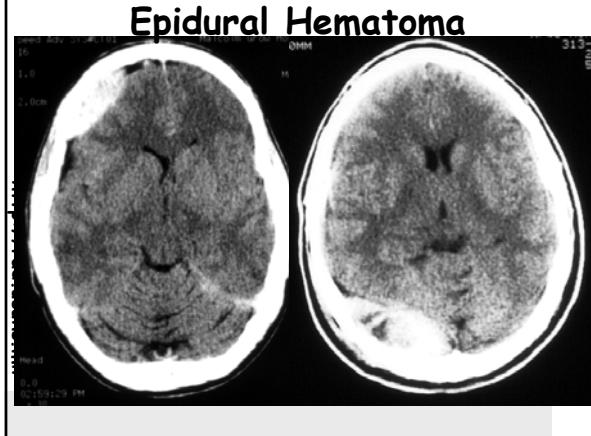
### Epidural Hematoma



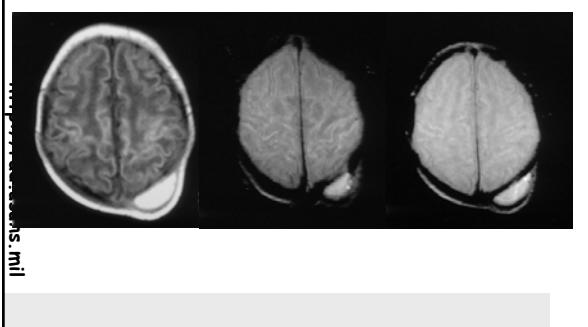
### SUBPERIOSTEAL HEMATOMA

- CEPHALOHEMATOMA
  - (Birth trauma)
  - (outer table, sub-periosteal)
- EPIDURAL HEMATOMA
  - (Inner table, "sub-periosteal")

### Epidural Hematoma



### Cephalohematoma Birth Trauma



## SUBDURAL HEMATOMA

- Extremes of age
  - Infants/elderly
- Subacute presentation
  - Days or weeks after trauma
- Fracture not needed
- Crescentic
  - Not hyperdense
  - Crosses sutures commonly
  - Interhemispheric fissure (kids)
- Epi - Arachnoid

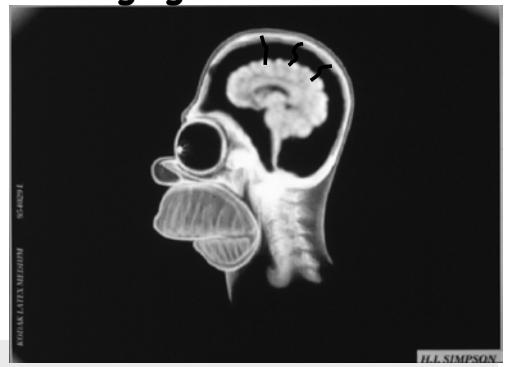
## SUBDURAL HEMATOMA

- ACCELERATION-DECELERATION
  - Causes OSCILLATION OF BRAIN
  - Movement of Brain LAGS behind Skull
- BRIDGING VEINS STRETCH & TEAR
  - Venous bleeding (slow)
- DISSECTION OF SUBDURAL SPACE
  - Under Dura - Over Arachnoid
- Hematoma spreads around convexity
- Into the interhemispheric fissure (child)

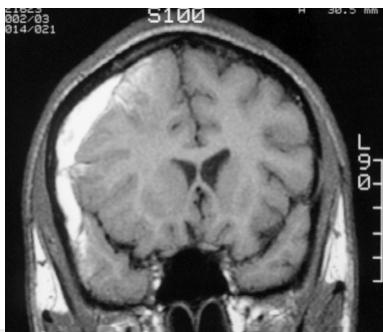
## SUBDURAL HEMATOMA - Source of Blood

- LACERATION OF CORTICAL AA. AND VV
  - (Direct: penetrating injury)
- LARGE CONTUSIONS
  - (Direct/indirect: "pulped brain")
- TORN BRIDGING (CORTICAL) VEINS
  - (Indirect: acceleration-deceleration)

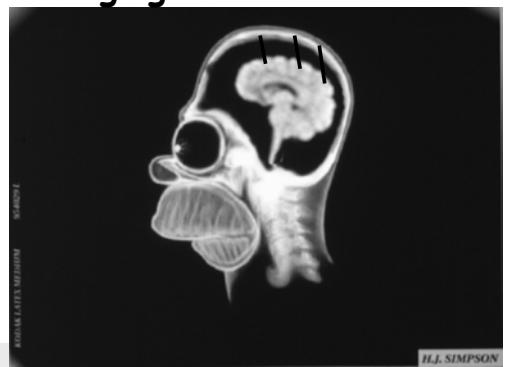
## Bridging Veins - Slack



## Subdural Hematoma



## Bridging Veins - Tension



### Bridging Veins - Tension



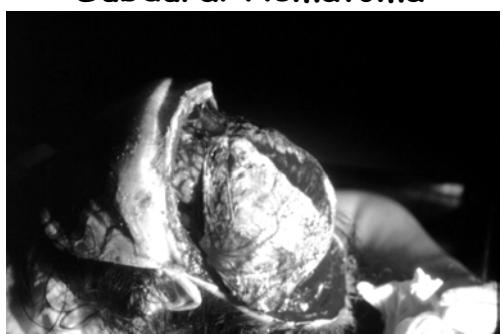
### Hyperdense SDH



### Bridging Veins - Tear



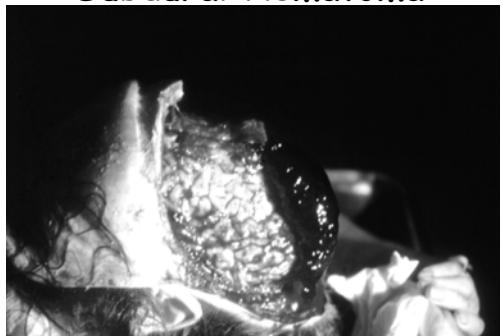
### Subdural Hematoma



### Subdural Hematoma



### Subdural Hematoma



## SUBDURAL HEMATOMA

- ACUTE (0-7 days)
  - HYPERDENSE (65-90 Hu)
- SUBACUTE (7-22 days)
  - ISODENSE (20-40 Hu)
- CHRONIC (>22 days)
  - HYPODENSE (0-20 Hu)

<http://radiopaedia.org>

## Hypodense SDH

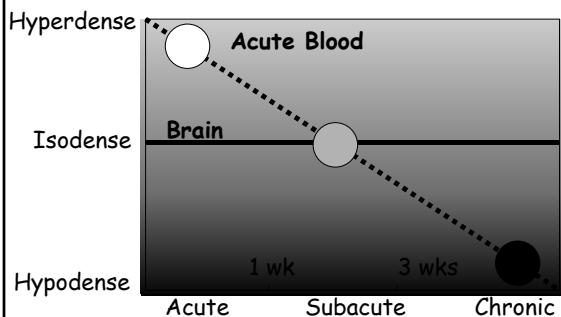


## SUBDURAL COLLECTIONS

- Acute SDH - hyperdense
- Subacute SDH - isodense
- Chronic SDH - hypodense
- Hygromas
  - Hypodense, isointense to CSF
  - CSF leak from arachnoid tears
- Effusions
  - Hypodense(meningo-encephalitis, esp. H.flu)

<http://radiopaedia.org>

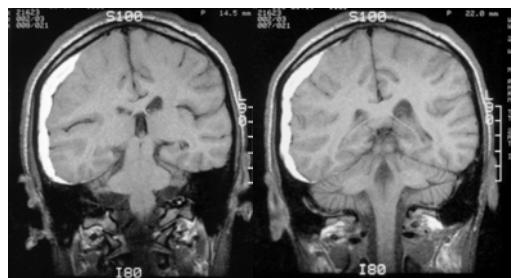
## Hemorrhage: change over time



## Isodense subdural



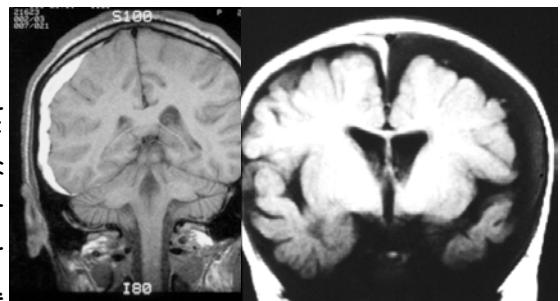
## Subdural Hematoma



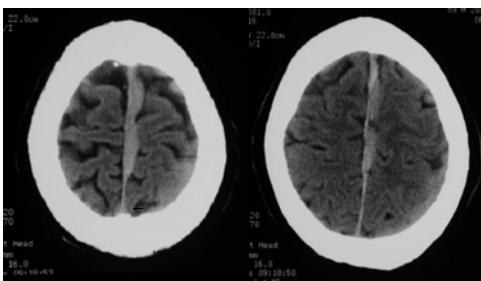
### Interhemispheric Subdural



### Subdural Hematoma



### Interhemispheric Subdural



### Subdural = Epi - Arachnoid



### INTERHEMISPHERIC FISSURE and the FALX SIGN

- Normal Falx:
  - thin white line, may see CSF parallel
- Subarachnoid Blood:
  - anterior, zig-zag, reaches the corpus callosum
- Subdural Hematoma:
  - posterior, straight, doesn't touch the corpus callosum

### SUBDURAL HEMATOMA

- 2-3 wks. to develop fully
- develop from outer (dural) margin
- not from arachnoid side
  - inner (arachnoid) border intact
- fibroblasts, and new immature capillaries that are fragile

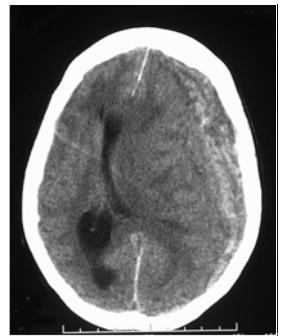
## Neomembrane from Dura



<http://rad.usmhs.edu>

## Acute-subacute Subdural Hematoma

- Acute blood-bright
- Alternating bands
  - rebleeding
- Mass effect
  - Subfalcial herniation
  - "Trapped" ventricle



## SUBDURAL HEMATOMA - Source of Re-bleeding

- NEO-MEMBRANES
  - fragile capillaries
- BRIDGING VEINS
  - stretching across SDH
  - constant tension

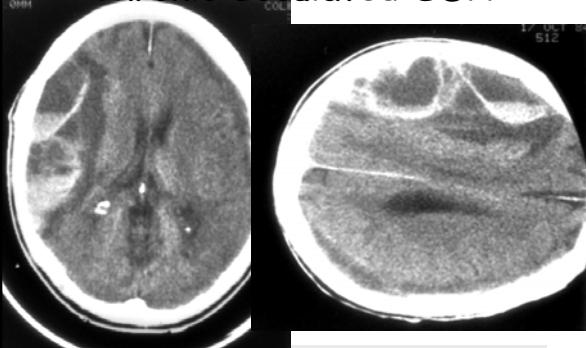
<http://rad.usmhs.edu>

## Subdural Hematoma



<http://rad.usmhs.edu>

## Chronic Loculated SDH



<http://rad.usmhs.edu>

## Subdural Hematoma

- Under the Dura
  - "Sub-Dural"
- Over the Arachnoid
  - "Epi-Arachnoid"
- Actually between the "Dural Border Cells" the "Arachnoid Barrier Layer"

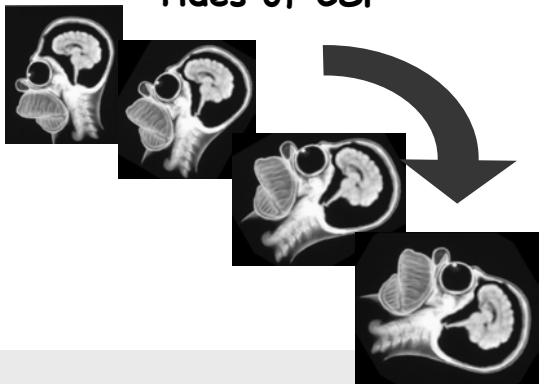
Schachenmayer and Friede, Am J Path (1978); 92: 53 - 68

## CEREBRAL CONTUSION

- Traumatic/mechanical disruption of small (capillary) vessels
- Extravasation of whole blood, plasma (edema) and RBC's
- Admixture of blood mixed with native tissue (petechial hemorrhage)
- Mottled / speckled density ("salt and pepper" on CT)

<http://rad.usuhs.mil>

## Tides of CSF



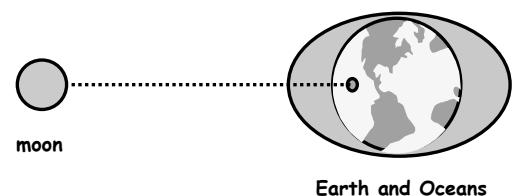
<http://rad.usuhs.mil>

## CEREBRAL CONTUSION (naming conventions)

- COUP (SAME SIDE AS IMPACT)
  - (w/fractures, small area of impact)
- INTERMEDIATE (CENTRAL)
  - (DAI/Shearing Injury)
- CONTRE - COUP (OPPOSITE IMPACT)
  - (w/falls, broad surface of impact)

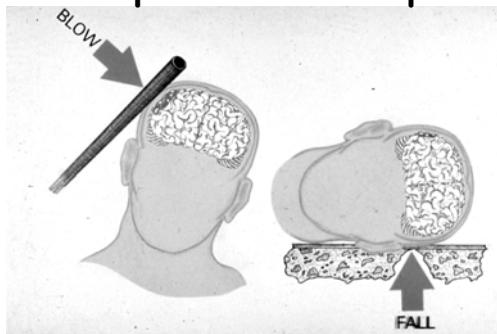
<http://rad.usuhs.mil>

## High Tide / Low Tide



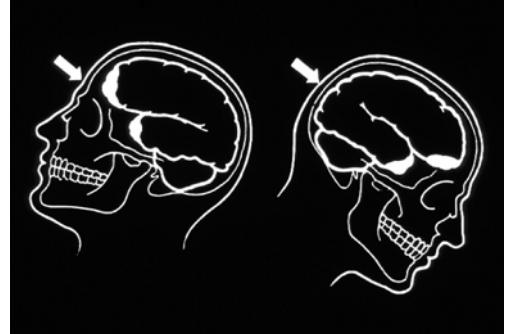
<http://rad.usuhs.mil>

## Coup vs. Contrecoup



<http://rad.usuhs.mil>

## Coup vs. Contrecoup

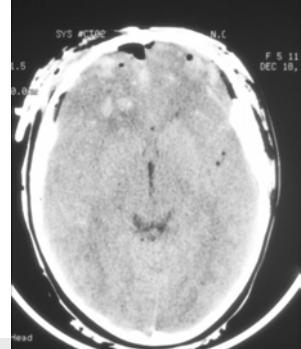


<http://rad.usuhs.mil>

## CEREBRAL CONTUSION

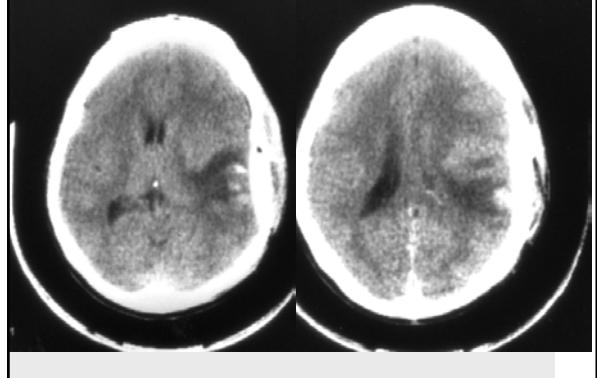
- MECHANICAL INJURY TO VESSELS
  - Extravasation of whole blood
- PETECHIAL / PERIVASCULAR HEMORRHAGE
  - Admixture of tissue and blood
  - average density may NOT be high
- SWELLING/MASS EFFECT
- MAY PROGRESS TO HEMATOMA
  - If larger vessels are damaged
  - large confluent mass of blood

## Cerebral Contusion

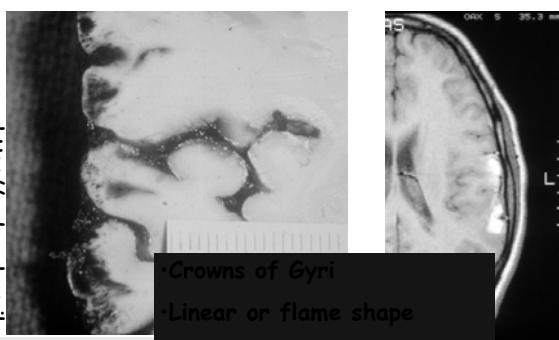


Temporal Tips  
Orbitofrontal Gyri

## Cerebral Contusion



## Cerebral Cortical Contusion

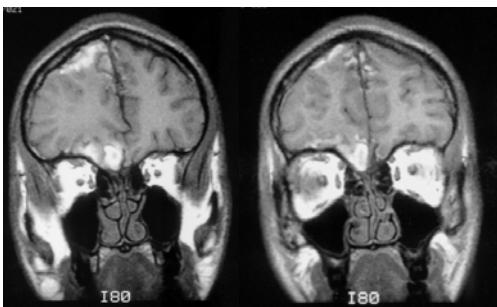


• Crowns of Gyri  
• Linear or flame shape  
• NOT in depths of Sulci

## CEREBRAL CONTUSION

- CT Hypodense (EDEMA)
  - Isodense (mass)
  - Hyperdense(mottled, speckled)
- MR Variable Intensity
  - (GRE) - Hypointense
  - Hyperacute Blood
- COUP CONTUSION
  - ASSOCIATED w/Fx

## Cerebral Contusion



## SHEARING INJURIES

- Deep lesions
- High Velocity (MVA) Trauma
- Acceleration/Deceleration
- Do not require an impact or Fx
- **SHEARING OF AXONS**
  - Breaks connections
  - Actual force may be tension
- **SHEARING of Small WM VESSELS**
  - Small (petechial) hemorrhages

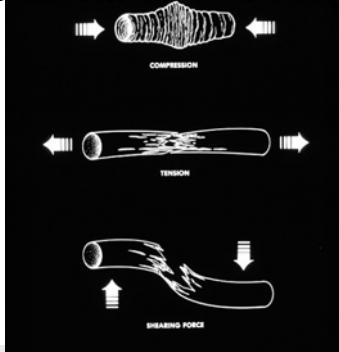
## Deep Lesions - Terminology

- Intermediate Contusions
- Shearing Injury
- Diffuse White-matter Injury (DWI)
- Diffuse Axonal Injury (DAI)

## Deep Lesions

- Subcortical and Hemispheric WM
- Corpus Callosum
  - posterior body
  - splenium
- Brain stem
  - Dorsolateral Quadrant of Upper BS
  - Deep BS
  - Ventral BS

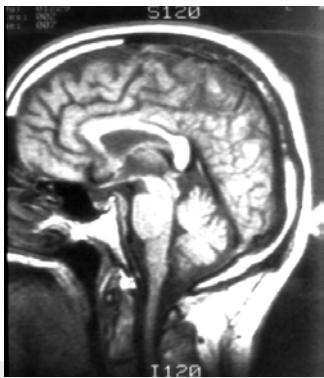
## Mechanism of Axon Injury



## DIFFUSE AXONAL INJURY

- Immediate L.O.C. Persistent Vegetative State
- Pathology:
  - foci of hemorrhage in callosum, brainstem, etc.
  - axon retraction balls (ARB)
- Long-Term Survivors:
  - microglial clusters
  - foci of demyelination

<http://rad.usuhs.mil>



<http://rad.usuhs.mil>



<http://rad.usuhs.mil>



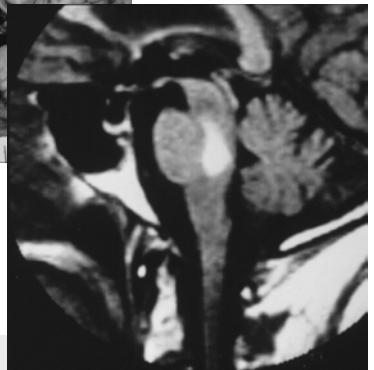
### Pontomedullary Tear



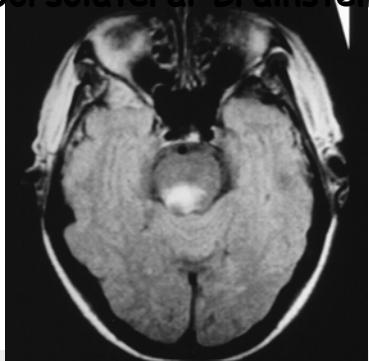
<http://rad.usuhs.mil>



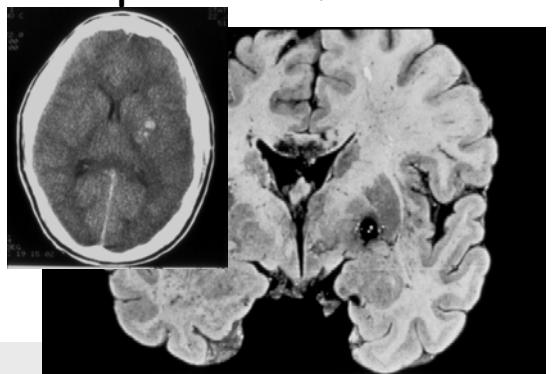
### Brainstem Hemorrhage



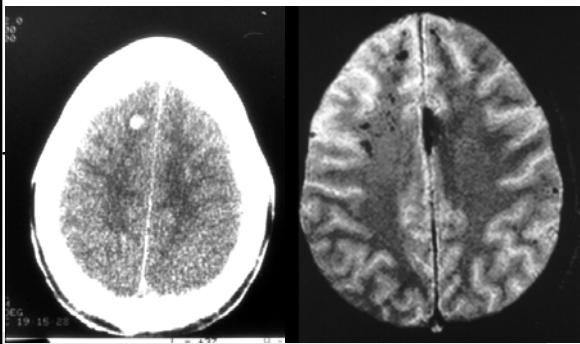
Dorsolateral Brainstem



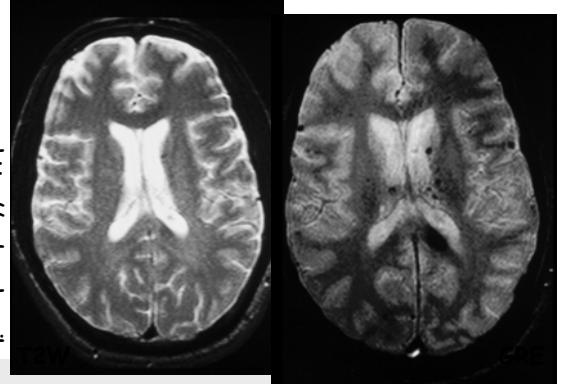
Corpus Callosum and BG



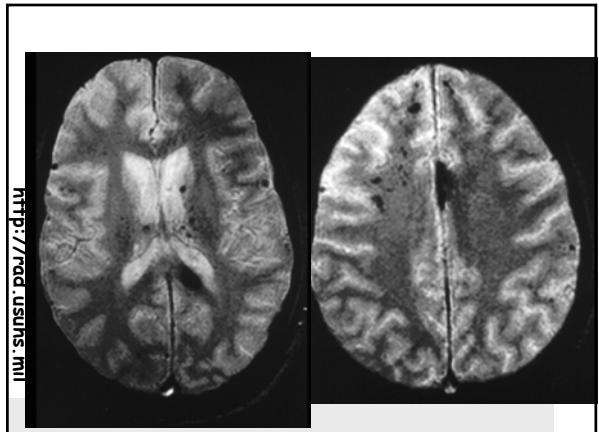
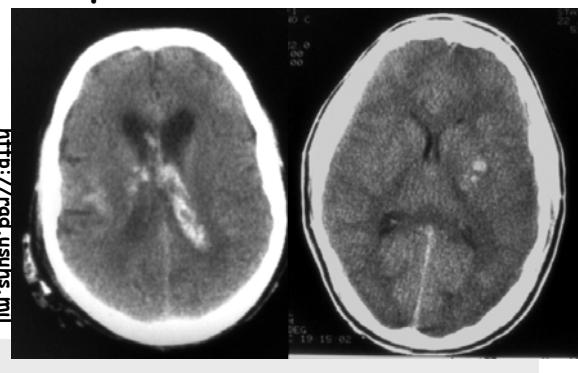
CT vs. MR (GRE)



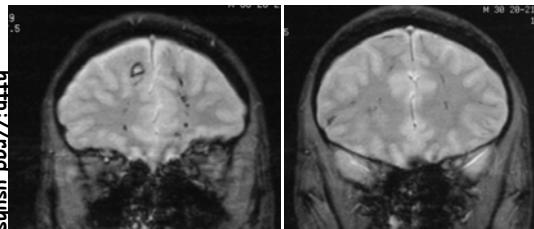
T2W vs.. GRE (Gradient Recalled Echo)



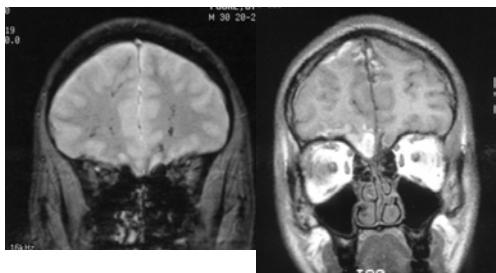
Corpus Callosum -> Ventricle



## Shearing Injury - Deep Lesions



## Shearing Injury vs. Contusion



## CNS TRAUMA - Summary



- Epidural Hematoma (subperiosteal)
  - acute, convex, white
- Subdural hematoma (epi-arachnoid)
  - variable shape, density, age
- Contusion (petechial)
  - Surface - cortex. coup/contra
  - Dark on GRE - CT "speckled"
- Shearing injury (DAI)
  - Deep - subcortical WM, corpus callosum and & basal ganglia